



## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(54) Title: BIODEGRADABLE CONTROLLED RELEASE MATRICES (57) Abstract <p>This invention relates to a biodegradable or digestible matrix and in particular, to a matrix suitable for controlled release of an active agent into an environment or for controlled rate of biodegradation or digestion. The matrix includes an amylaceous material or derivative thereof, less than about 25 % w/w of a synthetic polymer and an active agent to be released. The invention also relates to a method for manufacture of the matrix wherein a hot melt is prepared by heating and subjecting to pressure a composition comprising an amylaceous material or a derivative thereof and sufficient water to provide a melt for subsequent forming into a matrix shape. The matrix shapes according to the invention are particularly suitable for use in agriculture.</p>		

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Title: BIODEGRADABLE CONTROLLED RELEASE MATRICES

TECHNICAL FIELD

This invention relates to a biodegradable or digestible matrix, and more particularly to a matrix suitable for controlled release of an active agent into an environment or for controlled rate of biodegradation or digestion. The invention also relates to a method for manufacture of the matrix and to the use of the matrix in agriculture.

BACKGROUND ART

In agriculture it is desirable to release fertilizers, pesticides, herbicides or the like active agents to the soil at a controlled rate over a prolonged period. Depending on the type of active agent and the

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agricultural requirement, the period of release may be desirably a period of weeks, months or years.

Furthermore, it is sometimes desirable that the active agent be released at an initially high rate and then at a slower rate.

It has been practised to prepare copolymers comprising a synthetic polymer as the major component with minor amounts of starch as absorbants. These grafted polymers are used in agriculture for example, as a coating for seeds. The polymer absorbs water and holds it at the seed surface, thus increasing both the rate of germination and the percentage of the total number of planted seeds which germinate. Examples include starch polyacrylates, starch acrylonitriles, starch polyethylenes, starch-vinyl copolymers and the like.

Similarly, it is known to manufacture so called biodegradable films from synthetic polymers for use in for example agriculture as mulch films. Some of these films include starch as a minor component.

However, in general, the starch-synthetic copolymer compositions and synthetic films suffer from the disadvantage that they are not truly biodegradable. Disadvantageously, when the composition disintegrates, the synthetic organic residue remains as an environmental pollutant.

It has also been practiced to encapsulate active

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agents so that an inner core of the toxic agent is surrounded by a polymeric matrix. The polymeric matrix may include starch. These products form a sponge like structure which holds the active ingredient when dry but releases it upon wetting. Release is generally effected by the rupture of the enveloping membrane. Accordingly, although these materials may be fully biodegradable, it is difficult to control the rate of release and also to control the rate of degradation. The production of such incorporated agents involves complex and critical manufacturing steps.

The present invention stems from the surprising and unexpected discovery that an active ingredient can be controllably released into an environment at a predetermined rate from a biodegradable matrix based on a starch derived material and that the release rate of the active ingredient can be varied independently of the rate of degradation of the matrix.

The biodegradable matrix of the invention has been developed primarily for use in agriculture and will be described hereinafter with reference to that application. However, it will be appreciated that the invention is not limited to that particular field of use.

#### DISCLOSURE OF THE INVENTION

It is a first object of the present invention to

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provide a method for the manufacture of a biodegradable matrix shape having an active agent incorporated therewith to be controllably released from the matrix into an environment at a predetermined rate.

It is a second object of the present invention to provide a biodegradable composition for the controlled release of an active ingredient into an environment which in preferred embodiments, avoids or at least ameliorates the above discussed deficiencies of the prior art.

According to one aspect, the invention consists in a method for manufacture of a biodegradable matrix shape containing an active agent to be released from the matrix at a predetermined rate, said method comprising the steps of:

- a) heating and subjecting to pressure a composition comprising an amylaceous material or a derivative thereof and water whereby to provide a uniform hot melt,
- b) forming the hot melt into a desired matrix shape, and
- c) incorporating the agent in the matrix shape.

According to a second aspect, the invention consists in a composition for biodegradation in an environment, said composition comprising a matrix including an amylaceous material or derivative thereof, from 0 to less than or equal to about 25% by weight of a synthetic polymer and an active agent intended to be

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released into the environment at a predetermined rate.

According to a third aspect, the invention consists in a method of agriculture which comprises applying to a crop growing area a matrix shape produced by the method according to the first aspect or the composition according to the second aspect.

For the purposes of this specification, the term "amylaceous material" means starch or flour from any cereal crop, root crop, leguminous crop or any other commercial source of starch and includes for example wheat starch, maize starch including waxy maize starch, potato starch, tapioca starch, pea starch or a combination thereof, amylose or amylopectin alone or any combination of amylose and amylopectin.

A "derivative" of amylaceous material includes modified amylaceous materials (for example chemically modified amylaceous materials), amylaceous compositions formed during hot melting or during forming amylaceous material alone or in combination with plasticizers, crosslinking agents or the like. The term also includes starch molecules having a synthetic polymer grafted thereon.

"Synthetic polymer" includes non-naturally occurring polymers such as those used for plastics and elastomers and the term includes within its scope both thermoplastic and thermosetting polymers.

The term "forming" in relation to the hot melt

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includes the formation of films, rods, strands, sheets, pellets or the like and includes, as the context admits, extrusion through a die head and in a blow moulding machine.

The present invention particularly relates to the controlled release of an active agent selected from the group comprising acaricides, insecticides, nematocides, herbicides, fungicides, plant growth regulants, fertilizers, trace nutrients or a combination thereof into an environment. Preferably the environment is a terrestrial environment and in a highly preferred embodiment the environment is a crop growing area. However, the invention will be understood to be suitable for use in aquatic environments.

#### BRIEF DESCRIPTION OF DRAWINGS

Preferred embodiments of the invention will now be described, by way of example only, with reference to the accompanying graphs wherein cumulative % weight loss is shown on the y axis, time of incorporation in soil (days) is shown on the x axis, soil temperature is shown in degrees Celsius and soil moisture represented by the symbols FP, H, M and L wherein FP represents a flood plot where excess water is present, H represent a high soil moisture content of from 26% to 40% by weight, M represents a medium soil moisture content of from 6% to



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20% by weight and L represents a low moisture content of from 3% to 17.6% by weight.

Figures 1 to 4 show the effect of soil moisture and soil temperature on the degradation rate of a biodegradable matrix according to the invention.

Figure 5 shows the effect on the degradation rate of the addition of a crosslinking agent to the amylaceous material during or after forming into a matrix shape.

Figures 6 and 7 show the effect of product shape on the degradation rate of the matrix.

Figures 8 to 10 show the effect of the incorporation of synthetic polymers on the degradation rate of the matrix.

Figures 11 and 12 show the effect of the incorporation of fillers on the degradation rate of the biodegradable matrix.

Figure 13 shows the variation in the release rate of the active agent that may be obtained by the selection of either carbosulfan, chlorpyrifos or phorate.

Figure 14 shows the effect of the introduction of an active agent on the degradation rate of the biodegradable matrix.

Figure 15 shows the release rate of the active agent from those matrices from figure 14 including an active agent.

Figure 16 shows the effect of the addition of 9%

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filler  $[(\text{NH}_4)_2\text{SO}_4]$  on the release rate of the active agent.

#### BEST MODES FOR CARRYING OUT INVENTION

The biodegradable composition according to the invention is desirably formed from a "hot melt" process.

In preferred embodiments of the method for manufacture according to the invention, a composition comprising an amylaceous material or a derivative thereof is first prepared by mixing an amylaceous material and an amount of water in sufficient proportion to form a free-flowing powder.

In preferred embodiments of the invention, the amylaceous material used is high amylose maize starch comprising at least 50% by weight of amylose or a modified derivative of this starch.

Where a high amylose maize starch is used, it is desirable to select a high amylose maize starch or modified starch derived from the Goodman Fielder Mills Pty Ltd maize hybrids 55/77 or 65/88 described in detail in the Applicant's co-pending application no. PCT/AU90/00237 incorporated herein by cross-reference.

By modifying the basic starch, it is possible to confer different properties on the final matrix shape. A large number of derivatives of amylaceous materials are suitable for use in the present invention. These

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include (i) ether derivatives such as a) hydroxyalkyl derivatives, for example hydroxyethyl, hydroxypropyl and hydroxybutyl and b) carboxyalkyl derivatives, for example carboxymethyl, and (ii) ester derivatives such as saturated fatty acid derivatives, for example acetyl and succenyl. Mixed derivatives are also suitable for use in the present invention.

In addition, the ether and ester derivatives may be crosslinked such as for example, distarch phosphate or distarch glycerol. In such case, modification may be achieved by using a crosslinking agent such as sodium trimetaphosphate. Cross bonded high amylose maize starch and cross bonded common wheat starch are particularly suitable modifications for use in the present invention. The amylaceous material may be precrosslinked, that is be crosslinked prior to or during conversion to the hot melt. However, preferably, the amylaceous material is crosslinked during forming and more preferably after forming by any suitable method readily understood by those skilled in the art. For example, in one embodiment the matrix shape is extruded into a bath comprising the crosslinking agent, saturation allowed to take place and the matrix removed and allowed to dry and cure.

Derivatives which confer various degrees of hydrophobicity to the finished composition are particularly desirable. Such derivatives include

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amylaceous alkylsuccinates and in particular, starch octenyl succinate and starch molecules having synthetic polymeric branches grafted thereon. However, carboxymethylated, hydroxypropylated and acetylated high amylose modified maize starch derivatives are preferred.

By selecting the starch modification, the mechanical properties of the matrix shape may be varied. For example, the selection of an acetylated high amylose starch having an acetyl value of about 2.5% or a hydroxypropylated high amylose starch having a hydroxypropyl value of up to about 3% allows higher processing temperatures to be utilized thereby resulting in films having improved handling characteristics in that the hot melt is less fluid and more rubbery in nature. Carboxymethylated starch derivatives having a carboxyl value of about 2% are also particularly suitable for use in the present invention.

The nature of the crosslinking agent and the stage at which the crosslinking agent is incorporated into the amylaceous material effects such physical properties of the matrix shape as biodegradability, release rate, flexibility, strength, surface finish and colour.

For a uniform hot melt phase to form, it is believed necessary that an amount of water be present in the composition used to form the hot melt. Preferably, the composition contains water in less than the minimum amount required to dissolve all the amylaceous solid

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material, that is the composition contains less than about 50% by weight of water. More preferably, the composition comprises from about 2% to about 30% by weight of water. However, the minimum amount of water required to form a uniform hot melt may be employed. Accordingly, the amount of water may vary down to a few percent. It is emphasised that these amounts represent the total amount of water in the composition used to form the hot melt and not the amount of added water. In fact, amylaceous material as normally dried in preparation typically comprises from 9 to 20% by weight of water and as such; the residual moisture inherent in the amylaceous material may be sufficient to enable the conversion of the composition into a hot melt and additional water need not be added or be added in small quantities only. However, preferably, water is added in an amount of less than 50% by weight, more preferably less than 20% by weight and most preferably from about 5% to about 15% by weight.

The amount of water may be selected so as to modify the physical properties of the final product. For example, the higher the water content, the higher the flexibility and the lower the strand strength of the matrix shape.

In addition to the amylaceous material and water, the composition for preparing the hot melt may also include optional ingredients such as synthetic polymers,

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fillers, plasticizers, weighting agents, U.V. stabilizers, pore structure modifiers and the like.

The Applicant has discovered that the addition of synthetic polymers during the preparation of the biodegradable matrix shape affects both the performance and processing of the matrix. Preferably, the synthetic polymer is added to the composition before processing to a hot melt, although it may be added during the conversion or be applied to the matrix shape itself during forming by way of co-forming or alternatively, the matrix shape may be coated immediately after forming, for example by way of spraying, brushing or dipping. The co-forming technique employed may be any one of those currently used in the plastic industry for example thermal lamination, co-injection or co-extrusion using the cast (flat die) method or strand die method or in blown film production.

The Applicant has discovered that the inclusion of a synthetic polymer in the biodegradable matrix shape results in a more absorbent product for some active agents and a matrix shape having a greater shelf life stability. Further, the Applicant has made the surprising and unexpected discovery that where an ethylene vinyl acetate starch copolymer is used, a two phase system forms in the cooled matrix. The presence of these two apparently continuous phases of starch and synthetic polymer results in a very high surface area

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honeycomb of the ethylene vinyl acetate phase once the starch phase has degraded. Further, the phase separation/compatibility may be adjusted by modifying the side chain components of the modified starches.

The synthetic polymer may be added in an amount of up to about 90% by weight of the composition, hot melt or the matrix shape respectively. However, preferably, no more than about 25% by weight and more preferably less than or equal to about 15% by weight synthetic polymer is added since in general, the larger the synthetic polymer component, the slower the degradation rate of the matrix shape.

The synthetic polymer may be any conventional thermoplastic or thermosetting polymer but is preferably selected from the group consisting of polyethylene (including low density polyethylene, linear low density polyethylene and high density polyethylene), ethylene vinyl acetate copolymers, ethylene acrylic acid copolymers, polyvinyl chlorides, polystyrenes, chlorinated polyethylenes, ethylene propylene copolymers, acrylic acid copolymers, polyvinyl acetals copolymers, polyamines, polyethylene terephthalates, phenolic resins and urethanes. Most preferably, the synthetic polymer is thermoplastic and is low density polyethylene, linear low density polyethylene, or high density polyethylene; an ethylene vinyl acetate copolymer having a vinyl acetate content of from 5% to

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40% W/W and melt flow index of from 0.5 to 400 g/10 minute as determined by the ASTM test D1238; or polyvinyl chloride or chlorinated polyethylene having a chlorine content of from 20% to 50% W/W.

The synthetic polymer may be selected to modify or decrease both the biodegradation rate of the matrix shape and the release rate of the active agent. Further, the Applicant has found that the addition of a synthetic polymer to the matrix affects the mechanical properties of the finished article. For instance, at the 10% addition level both chlorinated polyethylene and polyvinyl chloride increase strand strength and flexibility of the final matrix shape. Conversely, at the 10% addition level, ethylene vinyl acetate copolymers decrease strand strength yet increase flexibility. Both strand strength and flexibility are advantageous for the purposes of handling and storage of the finished product as matrices exhibiting these properties tend to retain their shape and integrity.

The addition of non polymeric fillers also serves to modify processing and performance characteristics of the hot melt and final product. Fillers may be added to the composition prior to conversion into the hot melt or be added to the hot melt prior to formation of the matrix shape. Water soluble, water insoluble, organic, inorganic, ionic and non-ionic fillers are suitable for use in the present invention. Preferably, the selected



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filler is non-toxic to the environment. Specific examples of suitable fillers include metal salts, clays, carbonaceous materials, dextrose, talc, silicas and ammonium sulphate. Preferably, the metal salt is calcium carbonate, calcium sulphate, sodium carbonate, sodium sulphate or barium sulphate, the clay kaolin or bentonite and the carbonaceous material wood flour. The fillers may be included in the formulation at levels up to about 70% by weight. However, formulations comprising up to about 95% by weight non polymeric filler are also envisaged by the present invention.

The addition of plasticizers and lubricants improves both the extrusion characteristics of the hot melt and the physical properties of the matrix shape. The plasticizer may be added to the composition prior to conversion into the hot melt or to the hot melt prior to formation. Generally, any known plasticizer can be utilized in the present invention. However, specific examples of suitable plasticizers include mono or polyfunctional alcohols. Polyethylene glycol, acetyl glycol, glycerol, invert sugar, dioctyl phthalate, vegetable oils (preferably soya bean oil), chlorinated hydrocarbons and combinations thereof are preferred.

The amount of plasticizer to be used will vary up to about 20% by weight of the formulation. However, the presence of an auxiliary plasticizer is not essential.

In order for the hot melt to form, the amylaceous

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containing composition must be subjected to elevated temperatures and pressure. The temperatures best suited for this conversion are from about 70°C to 200°C depending on the formulation. Where the matrix shape is formed without vacuum venting, the preferred temperature is about 90°C in all heating zones. However, where the active agent has been incorporated before or during processing, the conversion and forming steps respectively are preferably performed below the temperature at which the active agent breaks down. Where the active agent is incorporated with the matrix shape after forming, higher processing temperatures may be used providing the matrix shape is cooled or allowed to cool prior to incorporating the active agent therewith. The preferred pressure for conversion of the amylaceous containing composition to a hot melt is from about 60 psi to about 2000 psi.

In one embodiment, the hot melt is subjected to a reduced pressure immediately prior to the forming step to remove water and other volatiles from the hot melt. This step is especially desirable where the melt is to be extruded as a film. Desirably, the reduced pressure is in the form of a vacuum stripping step at a pressure of for example less than 200 mbar. Alternatively, the hot melt is subjected to a series of reduced pressures prior to the forming step to sequentially remove a portion of the water and other volatiles from the hot

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melt at each venting step.

The hot melt is then formed into the desired matrix shape by any conventional process such as dies or rolls into any desired size or shape including pellets, chips, ribbons, films and the like.

In another embodiment of the invention, the matrix obtained from the process described hitherto and an amount of water sufficient to form a uniform hot melt is subsequently subjected to elevated temperatures and pressures for conversion into a second hot melt which can be shaped or moulded by any conventional process into the desired shape and size as described above.

If desired, some or all of the optional ingredients such as synthetic polymers, fillers, plasticizers and the like hitherto described may be added before, during or after this second processing step in accordance with the teachings set forth above.

The active agent may be added in powder or liquid form as part of the formulation before conversion to either the first or second hot melt, during either conversion or be incorporated with either the first or second matrix shape during or after forming for example, by way of immersion or infusion. Preferably, the active agent is incorporated during the final forming step when the active ingredient may be intimately mixed with the hot melt.

The active agent is preferably selected from the

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group comprising acaricides, insecticides, nematocides, herbicides, trace nutrients, plant growth regulants, fertilizers, fungicides or the like, or a combination thereof.

Representative examples of acaricides, insecticides and nematocides known to those skilled in the art include the following available chemicals, expressed by common name: cadusafos, carbofuran, carbosulfan, chlorfenvinphos, chlormephos, chlorpyrifos, chlorpyrifos-methyl, cloethocarb, cyhalothrin, deltamethrin, alphamethrin, dicrotophos, disulfoton, endosulfan, ethiofencarb, ethoprophos, fenamiphos, fensulfothion fonofos, furathiocarb, isazofos, methomyl, monocrotophos, oxamyl, parathion-methyl, parathion, phorate, pirimicarb, pirimiphos ethyl, pirimiphos methyl, quinalphos, tefluthrin, temephos, terbufos.

Herbicides to be used in the composition of the present invention depend on the plant desired to be destroyed. Therefore, the class of herbicides known to those skilled in the art for destroying undesirable plants are active agents within the concept of the present invention. Representative examples of herbicides, expressed by common name, include the following:

ametryn, amitrole, atrazine, bromoxynil, chlorsulfuron, cyanazine, 2,4-D and related compounds, desmethryn, di-allate, diquat, diuron, EPTC glyphosate linuron, MCPA

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and derivatives, metolachlor, metribuzin, paraquat, pendimethalin, picloram, simazine, terbutryn, triallate, triclopyr, trifluralin.

Similarly, the fungicides to be used in the composition of the present invention depends upon on the fungi desired to be destroyed. Representative examples of fungicides known to those skilled in the art and suitable for use in the present include the following expressed by common name: benalaxyl, benomyl, chlorothalonil, etridiazole, fosetyl, phosphoric acid and its salts and derivatives, imazalil, metalaxyl, pyrazophos, quintozone, triadimefon.

Specific examples of plant growth regulants, that is compounds especially formulated to make a specific portion of the plant grow faster than others, and other compounds suitable for incorporation with the matrix shape include:

chlormequat, nitrapyrin, paclobutrazol, urea, monoammonium phosphate, diammonium phosphate, chelated trace elements, trace nutrients, potassium sulphate, ammonium sulphate, potassium ammonium sulphates.

Suitable trace nutrients include those compounds recognised as essential or desirable for healthy plant growth and include amongst others, oxides and salts of trace elements utilized by plants.

The nature of the active agent may be selected on the basis of the desired release rate of the final

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biodegradable composition.

The biodegradable compositions according to the invention comprise a matrix including an amylaceous material or derivative thereof, from 0 to less than or equal to about 25% by weight of a synthetic polymer and an active agent intended to be released into an environment at a predetermined rate. Preferably, the matrix comprises less than or equal to about 15% by weight synthetic polymer.

Desirably, the matrix is formed from an amylaceous hot melt and more desirably, by the method described above. The amylaceous material or derivative thereof and synthetic polymer may be any one of the products already described. Additionally, the matrix may include other optional ingredients such as fillers, plasticizers, weighting agents, U.V. stabilizers, pore structure modifiers and the like, the nature of which has been discussed previously.

Preferably, the final matrix includes water in an amount of from about 1% to about 50% by weight and more preferably, from about 2% to about 30% by weight.

The biodegradable matrix shapes and compositions according to the invention are particularly suitable for use in agriculture where they are applied for example, as pellets or ribbons to a crop growing area to improve plant growth and yield over an extended period of time. The matrix shapes and compositions may be applied on top

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of the soil but desirably, they are applied within the soil. They may be applied to the crop growing area by any conventional means including ploughing, tilling, banding, cultivating, furrowing and the like.

The release of the active agent from the biodegradable matrix is thought to be effected by two main mechanisms, diffusion through the matrix and by leaching through pores either inherent in the matrix or induced by the leaching out of soluble salts during service. Further, as the matrix is itself degrading during service, variations in the matrix surface area exposed to the environment also affects the rate of release indirectly so the release rate of the active agent may be controlled to an extent by controlling the rate of biodegradation of the matrix.

As illustrated by the following examples, and with reference to figures 1 to 16, it is possible to select both the release rate and biodegradation rate of the matrix shape by the selection of starch type, additives to be incorporated into the matrix, active agent type and processing conditions.

The formulations represented by figures 1 to 16 are depicted in the following table.

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TABLE 1

% W/W OF FORMULATION	1A	1B	2A	2B	3A	3B	3C	4A	4B	5A	5B
A877 <sup>1</sup>	63.0		72.1	72.1						56.6	56.6
Gelose 50 <sup>2</sup>		62.0			52.8	52.8	52.8	62.0	62.0		
Gelose 22 <sup>3</sup>											
H <sub>2</sub> O	15.6	30.0	16.1	16.1	25.5	25.5	25.5	30.0	30.0	13.5	9.9
Glycerol	11.4	8.0	11.8	11.8	6.8	6.8	6.8	8.0	8.0	10.8	10.8
Dextrose	10.0										
Omyacarb 10 <sup>4</sup>											
BaSO <sub>4</sub>											
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>											
Kaolin											
EVA <sup>5</sup>					14.9	14.9	14.9				
Sodium Trimeta Phosphate											3.6
NaHCO <sub>3</sub>										9.0	9.0
Active Agent											
1 <sup>6</sup>											
2 <sup>7</sup>										10.1	10.1
3 <sup>8</sup>											
CPE <sup>9</sup>											



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Table 1 - Continued

% W/W OF FORMULATION	6A	6B	7A	7B	8A	8B	8C	8D	9A	9B	9C
A877 <sup>1</sup>	56.6	56.6			72.1	63.0	31.4	7.8	72.1	63.0	31.4
Gelose 50 <sup>2</sup>											
Gelose 22 <sup>3</sup>			64.7	64.7							
H <sub>2</sub> O	9.9	9.9	14.4	14.4	16.1	15.6	7.8	2.0	16.1	15.6	7.8
Glycerol	10.8	10.8	10.6	10.6	11.8	11.4	5.7	1.4	11.8	11.4	5.7
Dextrose											
Omyacarb 10 <sup>4</sup>											
BaSO <sub>4</sub>											
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>											
Kaolin											
EVA <sup>5</sup>						10.0	55.1	88.8		10.0	55.1
Sodium Trimeta Phosphate	3.6	3.6									
NaHCO <sub>3</sub>	9.0	9.0									
Active Agent											
1 <sup>6</sup>	10.1	10.1	10.3	10.3							
2 <sup>7</sup>											
3 <sup>8</sup>											
CPE <sup>9</sup>											

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Table 1 - Continued

% W/W OF FORMULATION	9D	10A	10B	11A	11B	11C	11D	11E	13A	13B	13C
AS77 <sup>1</sup>	7.8	63.0	63.0	72.1	63.0	63.0	63.0	63.0			
Gelose 50 <sup>2</sup>											
Gelose 22 <sup>3</sup>									64.7	63.8	64.5
H <sub>2</sub> O	2.0	17.6	17.6	16.1	15.6	15.6	15.6	15.6	14.4	14.2	14.4
Glycerol	1.4	9.4	9.4	11.8	11.4	11.4	11.4	11.4	10.6	10.4	10.5
Dextrose											
Omyacarb 10 <sup>4</sup>							10.0				
BaSO <sub>4</sub>					10.0						
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>						10.0					
Kaolin								10.0			
EVA <sup>5</sup>	88.8										
Sodium Trimeta Phosphate											
NaHCO <sub>3</sub>											
Active Agent											
1 <sup>6</sup>									10.3		
2 <sup>7</sup>										11.6	
3 <sup>8</sup>											10.6
CPE <sup>9</sup>		10.0	10.0								

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Table 1 - Continued

% W/W OF FORMULATION	14A	14B	14C	15A	15B	16A	16B
AS77 <sup>1</sup>							
Gelose 50 <sup>2</sup>	47.9	52.8	47.3	47.9	47.3		
Gelose 22 <sup>3</sup>						63.8	55.7
H <sub>2</sub> O	23.1	25.5	22.8	23.1	22.8	14.2	13.8
Glycerol	6.2	6.8	6.1	6.2	6.1	10.4	10.1
Dextrose							
Omyacarb 10 <sup>4</sup>							
BaSO <sub>4</sub>							
(NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>							8.8
Kaolin							
EVA <sup>5</sup>	13.5	14.9	13.4	13.5	13.4		
Sodium Trimeta Phosphate							
NaHCO <sub>3</sub>							
Active Agent							
1 <sup>6</sup>	9.3			9.3			
2 <sup>7</sup>			10.4		10.4	11.6	11.6
3 <sup>8</sup>							
CPE <sup>9</sup>							

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1. A877 - Acetylated high amylose maize starch.
2. Gelose 50 - High amylose maize starch.
3. Gelose 22 - Hydroxypropylated high amylose maize starch.
4. Omyacarb 10 - One grade of  $\text{CaCO}_3$  (filler).
5. EVA - Ethylene vinyl acetate copolymer (20% vinyl acetate content).
6. Chlorpyrifos.
7. Carbosulfan.
8. Phorate.
9. Chlorinated Polyethylene (36% Cl Content).

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All formulations in table 1 were preblended to form a free flowing uniform mixture and extruded through a twin screw, co-rotating, intermeshing extruder having six barrel segments each with separate heating and cooling supply and a die containing an additional two heating zones. The extruder screws were of constant root diameter with an constant diameter ratio of 25:1.

The initial moisture content and active agent content of each matrix was determined and the matrix sample incorporated in soil. Said samples were analysed at periodic intervals for weight loss and active agent loss.

Degradation of the samples were calculated as follows:

Total weight

$$\text{Loss} = 100 - \frac{[\text{Dry Weight Retrieved}]}{\text{Dry Weight Established}} \times 100\%$$

$$= 100 - \frac{[(\text{Sample Weight} \times \text{Moisture Content}) \text{ Retrieved}]}{(\text{Sample Weight} \times \text{Moisture Content}) \text{ Established}} \times 100\%$$

Release rates were calculated as follows:

Release Rates

$$= 100 - \frac{[(\text{Sample Weight} \times \text{Active Content}) \text{ Retrieved}]}{(\text{Sample Weight} \times \text{Active Content}) \text{ Established}} \times 100\%$$

Figures 1 to 4 show the variation in the degradation rate of typical matrix formulations as a function of soil moisture and temperature.

From the results obtained, it is evident that the release rates and biodegradation rates of the matrices according to the invention are affected by both their

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solubility in water and soil temperature.

Figure 1 shows the large difference in degradation rate and total weight loss obtainable over a period of 168 days for two formulations 1A and 1B under vastly different soil conditions, that is in a flood plot at 30°C and a low moisture soil at 15°C. Figures 2 and 3 show typical degradation rates and total weight losses exhibited by a third formulation under flood plot (2A) and medium moisture conditions (2B) at a constant temperature of 30°C over a period of 35 days. Figure 3 compares the degradation rates and total weight losses exhibited by a fourth formulation over 168 days at 30°C in high (3A), medium (3B) and low (3C) soil moisture conditions. Figure 4 compares the degradation rates and total weight losses exhibited by the formulation shown in figure 1 as 1B at two soil temperatures [30°C (4A) and 15°C (4B)] but under constant soil moisture conditions. From these results it is evident that the higher the soil temperature and moisture content, the greater the amount and the faster the rate of degradation of the matrix over the specified time period.

Nevertheless, by modifying the solubility of the matrix it is possible to alter both the release rate of the active agent and the degradation rate of the matrix independently of soil conditions. For example, the release rate may be reduced by the selection of specific

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starch modifications which alter the hydrophobicity of the starch thereby preventing or deterring the dissolution of the starch matrices in wet environments or by modifying the starch by the introduction of active groups onto the starch chains which interact with the active agent thereby slowing down the leach out rate.

Conversely, the selection of a modified starch having reduced chain lengths induced, for example, by acid or enzyme modification, will result in a matrix exhibiting an increased rate of release.

The selection of a precrosslinked amylaceous material for subsequent conversion to the hot melt yields, after forming, a matrix shape which exhibits a relatively fast rate of release and degradation. This is somewhat surprising because crosslinked starches are typically more resistant to degradation and it is believed that this property is adversely affected by the forming step of extrusion. Conversely, where the amylaceous material is crosslinked during or after the forming step, the resulting matrix shape exhibits a slower rate of release and degradation. It is believed that this change in degradation and release rate is attributable to formation of an internally crosslinked continuous phase when the amylaceous material is crosslinked during or after forming and that this continuous phase is less susceptible to degradation. Conversely, it is thought that the use of a

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precrosslinked amylaceous material results in a matrix shape having a series of crosslinked phases which are more susceptible to degradation.

Figure 5 shows the effect of crosslinking on the degradation rate and total weight loss exhibited by two matrices over a period of 14 days at a constant soil temperature (30°C) and moisture condition (medium). The amylaceous material of matrix 5A is not crosslinked whereas the amylaceous material 5B was crosslinked after extrusion by the addition of sodium trimetaphosphate. From this figure it is evident that the degradation rate of a matrix may be reduced by the addition of a crosslinking agent after extrusion.

The selection of certain processing conditions will also affect the properties of the amylaceous material and therefore, the release rate of the active agent. For example, by increasing the rate of shear during processing, the resulting biodegradable matrix will have shorter chains, a more degraded structure and will therefore release the incorporated active agent at a faster rate.

The shape of the matrix will affect its degradation rate and therefore, to an extent, the release rate of the active agent therefrom as shown by figures 6 and 7 wherein matrix shapes 6A and 7A have a larger surface area than matrix shapes 6B and 7B respectively. From these figures it is evident that the larger the surface



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area to volume ratio of the matrix shape, the greater the degradation rate over the specified time period.

The incorporation of a synthetic polymer with the amylaceous material or matrix shape affects both the release rate and biodegradation rate of the matrix. It is thought that the synthetic polymers affect the intermolecular voids in the matrix and thereby, the rate of diffusion and leaching out of the active agent. It is also thought that they affect the mechanical properties of the starch molecules thereby effecting the strength and solubility of the matrix shape.

Figures 8 and 9 show the effect of increasing proportions of synthetic polymers on the degradation rate and total weight loss of four matrices in two soil moisture regimes, flood plot (FP) and high (H) at a constant soil temperature of 30°C. The results show little difference in the overall weight loss between the samples having 0 and 10% ethylene vinyl acetate respectively, but significant differences are apparent in both the rate of degradation and total weight loss exhibited by those matrices having higher amounts of ethylene vinyl acetate.

Figure 10 shows that there is not necessarily a detectable residue from a matrix having 10% synthetic polymer (chlorinated polyethylene) incorporated therein.

The nature and amount of filler may be used to control release rates. Where a water soluble filler is

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incorporated with the matrix, upon contact with moisture, the filler will dissolve over time, thereby creating a series of pores through which the active agent is actually released. Conversely, the incorporation of less soluble or insoluble inert fillers with the matrix reduces the release rate as the starch and active agent is "protected" from exposure to the environment and consequent dissolution.

Figure 11 shows the effect of the addition of a variety of fillers on the degradation rate and total weight loss of a matrix, other factors being constant.

The rate of degradation and total weight loss of the matrices of figure 11 as a function of soil moisture is illustrated in the family of curves of figure 12 wherein,

- a) the region between lines 12A and 12B represents the degradation rates and total weight losses of the matrices of figure 11, but excluding the formulation 11C comprising 10%  $(\text{NH}_4)_2\text{SO}_4$ , under medium (M) soil moisture conditions at a soil temperature of 30°C;
- b) the region between lines 12C and 12D represents the degradation rates and total weight losses of the matrices of figure 11 under high (H) soil moisture conditions at a soil temperature of 30°C and
- c) the region between lines 12E and 12F represents the degradation rates and total weight losses of the matrices of figure 11 under flood plot (FP) conditions

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at a soil temperature of 30°C.

From the figures it is evident that with the exception of the formulation comprising 10%  $(\text{NH}_4)_2\text{SO}_4$ , both the amount and rate of degradation and total weight loss observed for each formulation were substantially the same, regardless of the level of soil moisture present. However, the weight loss exhibited by the formulation comprising  $(\text{NH}_4)_2\text{SO}_4$  suggests that degradation was not just a result of dissolution of this water soluble filler.

The nature of the active agent will effect its rate of release. This is because different active agents will release at different rates under the same conditions, depending upon their water solubility, partition coefficients, cohesive energy densities, molecular size and other physical and chemical properties. Figure 13 shows the variation in release rates obtained where three different active agents were compared.

Figures 14 and 15 show that the release rate of any active agent is substantially independent of the biodegradation rate of the matrix. Figure 14 shows the cumulative % weight loss of three matrices whereas figure 15 shows the cumulative % weight loss of the respective active agents from the corresponding matrices shown in figure 14 under the same conditions.

In any event, the release rate of a given active

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agent may be varied by the selection of different amounts of the agent or the inclusion in the formulation of release rate modifiers such as fillers, synthetic polymers and the like. Figure 16 illustrates a modification to the release rate that may be achieved by comparing the total % weight loss of an active agent from a matrix comprising about 9% w/w ammonium sulphate (16B) with the total % weight loss of the same active agent from a similar matrix (16A). That graph clearly shows that incorporation of  $(\text{NH}_4)_2\text{SO}_4$  in the formulation increased the release rate of the active agent over the specified time period.

In summary, by selecting the appropriate starting materials and processing conditions, the release rates and degradation rates of the matrices according to the invention can be tailored for use in a range of environments so as to exhibit desired release rates and degradation rates.

It will be apparent that the biodegradable composition according to the present invention offers the following advantages:

- (a) the biodegradable composition provides for the controlled release of an active agent therefrom into an environment over a prolonged period as required,
- (b) the biodegradable composition may be tailored to exhibit a variety of release and degradation rates in a range of environments,

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(c) as apparent from the figures, where desired, the active agent can be released at an initially high rate and then at a slower rate as required,

(d) the matrix is biodegradable and over a period of time will break down in an environment.

Further, the use of the biodegradable matrices in compositions according to the invention is advantageous in that they exhibit reduced toxicity behaviour when compared with the toxicity of the active agent used alone or in conventional synthetic polymeric formulations as evident from the following dermal toxicity test carried out with moistened product in accordance the United States Environmental Protection Agency data generation guidelines.

In this regard, phorate was incorporated in a biodegradable matrix in accordance with the formulation show below in table 2:

TABLE 2 - TEST

<u>INGREDIENT</u>	<u>PERCENTAGE</u> <u>BY WEIGHT</u>
Gelose 50	64.5
Water	14.4
Glycerol	10.5
Phorate	10.6

Dermal toxicity tests using this formulation, a conventional synthetic polymer formulation comprising 10% w/w phorate and pure phorate (10% w/w) were

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performed on male rabbits by securing samples to the skin of the test animals for a period of 24 hours. At the expiry of this period rabbits were examined for mortality and surviving rabbits observed for 14 days before sacrifice and examination. The LD<sub>50</sub> values are shown below in table 3.

TABLE 3

<u>COMPOSITION</u>	<u>LD<sub>50</sub> DOSAGE MG PER KG</u> <u>BODY WEIGHT</u>
Formulation of Table 2	500 - 1000
Synthetic polymer formulation comprising 10% w/w phorate	56 - 71
Technical grade phorate (10% w/w)	5.2

It will be apparent to those skilled in the art from the teachings headed that the invention may be embodied in other forms without departing from the spirit or scope of the invention described.

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## CLAIMS:-

1. A method for manufacture of a biodegradable matrix shape containing an active agent to be released from the matrix at a predetermined rate, said method comprising the steps of:
  - a) heating and subjecting to pressure a composition comprising an amylaceous material or a derivative thereof and water whereby to provide a uniform hot melt,
  - b) forming the hot melt into a desired matrix shape, and
  - c) incorporating the agent in the matrix shape.
2. A method according to claim 1 wherein the agent is incorporated in the matrix shape by incorporating it in the composition in step (a).
3. A method according to claim 1 wherein the active agent is incorporated in the matrix shape by adding it to the hot melt prior to or during step (b).
4. A method according to any one of the preceding claims wherein the hot melt is formed into the desired matrix shape by extrusion.
5. A method according to any one of the preceding claims further comprising the step of (d) subjecting the hot melt to an atmospheric or sub-atmospheric pressure immediately prior to or during step (b) whereby to remove water from the hot melt prior to the formation of the matrix shape.
6. A method according to any one of the preceding

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claims wherein the amylaceous material or derivative thereof is selected or derived from the group consisting of amylose, maize starch including waxy maize starch, wheat starch, potato starch, tapioca starch, pea starch or a combination thereof.

7. A method according to claim 6 wherein the maize starch or pea starch is a high amylose starch comprising at least about 50% by weight of amylose.

8. A method according to any one of the claims 1 to 7 wherein the amylaceous derivative is selected from the group consisting of amylaceous ethers, esters, or a combination thereof; amylaceous alkyl succinates and starch molecules having synthetic polymeric branches grafted thereon.

9. A method according to claim 8 wherein the amylaceous ether or amylaceous ester is crosslinked.

10. A method according to claim 8 or 9 wherein the amylaceous ether is a hydroxyalkyl derivative or carboxyalkyl derivative.

11. A method according to claim 10 wherein the hydroxyalkyl derivative is hydroxyethyl, hydroxypropyl or hydroxybutyl and the carboxyalkyl derivative is carboxymethyl.

12. A method according to claim 8 or 9 wherein the amylaceous ester is a saturated fatty acid derivative.

13. A method according to claim 12, wherein the fatty acid derivative is an acetyl or succinyl derivative.



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14. A method according to claim 8 wherein the amylaceous alkyl succinate is starch octenyl succinate.

15. A method according to any one of the claims 1 to 7 further comprising the step of (e) crosslinking the amylaceous material or derivative thereof during or after step (b).

16. A method according to anyone of the preceding claims wherein the composition of step (a) comprises from about 2% to about 30% by weight of water.

17. A method according to claim 16 wherein the composition of step (a) comprises from 0 to about 50% by weight of added water.

18. A method according to claim 17 wherein the composition comprises less than about 20% added water.

19. A method according to claim 18 wherein the composition comprises from about 5% to about 15% by weight of added water.

20. A method according to any one of the preceding claims wherein the composition of step (a) comprises from greater than 0 to less than or equal to about 90% by weight of a synthetic polymer.

21. A method according to claim 20 wherein the composition of step (a) comprises less than about 25% by weight of a synthetic polymer.

22. A method according to claim 21 wherein the composition comprises less than about 15% by weight of synthetic polymer.

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23. A method according to any one of the claims 1 to 19 wherein a synthetic polymer is added to the hot melt in an amount in the range of from greater than 0 to less than or equal to about 90% by weight prior to or during step (b).

24. A method according to claim 23 wherein the synthetic polymer is added to the hot melt in an amount of less than about 25% by weight.

25. A method according to claim 24 wherein the synthetic polymer is added to the hot melt in an amount of less than about 15% by weight.

26. A method according to anyone of the claims 1 to 19 wherein in step (b), the matrix shape is co-formed with at least one layer of a synthetic polymer.

27. A method according to claim 26 wherein the matrix shape is co-extruded with the synthetic polymer.

28. A method according to any one of the claims 1 to 19 wherein the matrix shape from step (b) is coated with a synthetic polymer by way of spraying or brushing.

29. A method according to any one of the claims 20 to 28 wherein the synthetic polymer is selected from the group consisting of polyethylene including low density polyethylene, linear low density polyethylene and high density polyethylene, a copolymer of ethylene vinyl acetate, a copolymer of ethylene acrylic acid, polyvinyl chloride, polystyrene, chlorinated polyethylene, a copolymer of ethylene propylene, a copolymer of acrylic

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acid, polyvinyl acetals, polyamines, polyethylene terephthalate, phenolic resins and urethanes.

30. A method according to any one of the preceding claims wherein the composition of step (a) comprises a filler in an amount of less than about 95% by weight of said composition.

31. A method according to claim 30 wherein the composition comprises a filler in an amount of less than about 70% by weight of said composition.

32. A method according to any one of the claims 1 to 29 wherein a filler is added to the hot melt prior to or during step (b) in an amount of less than about 95% by weight of said hot melt.

33. A method according to claim 32 wherein the amount of filler added is less than 70% by weight of said hot melt.

34. A method according to any one of the claims 30 to 33 wherein the filler is selected from the group consisting of metal salts, clays, carbonaceous material, dextrose, talcs, silicas and ammonium sulphate.

35. A method according to claim 34 wherein the metal salt is calcium carbonate, calcium sulphate, sodium carbonate, sodium sulphate or barium sulphate.

36. A method according to claim 34 wherein the clay is kaolin or bentonite.

37. A method according to claim 34 wherein the carbonaceous material is wood flour.

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38. A method according to any one of the preceding claims wherein the composition of step (a) comprises a plasticizer in an amount of about 20% or less by weight.

39. A method according to any one of the claims 1 to 37 wherein a plasticizer is added to the hot melt in an amount of about 20% or less by weight of the hot melt prior to or during step (b).

40. A method according to claim 38 or 39 wherein the plasticizer is a mono- or polyfunctional alcohol.

41. A method according to any one of the claims 38 to 40 wherein the plasticizer is selected from the group consisting of polyethylene glycol, acetyl glycol, glycerol, invert sugar, dioctyl phthalate, vegetable oil, chlorinated hydrocarbons or a combination thereof.

42. A method according to claim 41 wherein the vegetable oil is soya bean oil.

43. A method according to any one of the preceding claims wherein the amylaceous material used in step (a) is the product of a method according to any one of the preceding claims.

44. A method according to any one of the claims 1 to 42 further comprising the steps of:

(f) heating and subjecting to pressure the matrix shape from step (b) and water whereby to provide a uniform hot melt; and

(g) extruding the hot melt of step (f) to form a further matrix shape.

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45. A method according to any one of the preceding claims wherein the active agent is selected from the group consisting of acaricides, insecticides, nematocides, herbicides, fungicides, plant growth regulants, fertilizers, trace nutrients or a combination thereof.

46. A method according to claim 45 wherein the active agent is chlorpyrifos, carbosulfan, carbofuran, phorate, diuron, or cerechlor.

47. A method according to any one of the preceding claims wherein the active agent is added to the composition of step (a) prior to the conversion to the hot melt.

48. A method according to any one of the claims 1 to 46 wherein the active agent is blended with the matrix shape from step (b) or step (g).

49. A method according to claim 48 wherein the active agent is incorporated with the matrix shape or further matrix shape by way of immersion or infusion.

50. A method according to any one of the preceding claims further comprising the step of (h) cooling or allowing the matrix shape to cool prior to incorporating the agent therewith.

51. A biodegradable matrix shape produced by the process according to anyone of the preceding claims.

52. A composition for biodegradation in an environment said composition comprising a matrix including an

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amylaceous material or derivative thereof, from 0 to less than or equal to about 25% by weight of a synthetic polymer and an active agent intended to be released into the environment at a predetermined rate.

53. A composition according to claim 52 comprising a matrix including less than about 15% by weight of a synthetic polymer.

54. A biodegradable composition according to claim 52 or 53 wherein the amylaceous material or derivative thereof is selected or derived from the group consisting of amylose, maize starch including waxy maize starch, wheat starch, potato starch, tapioca starch, pea starch or a combination thereof.

55. A composition according to claim 54 wherein the maize starch or pea starch is a high amylose starch comprising at least about 50% by weight of amylose.

56. A composition according to any one of claims 52 to 55 wherein the amylaceous derivative is selected from the group consisting of amylaceous ethers, esters or a combination thereof; amylaceous alkyl succinates and starch molecules having a synthetic polymer grafted thereon.

57. A composition according to claim 56 wherein the amylaceous ether or amylaceous ester is crosslinked.

58. A composition according to claim 56 or 57 wherein the amylaceous ether is a hydroxyalkyl derivative or carboxyalkyl derivative.

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59. A composition according to claim 58 wherein the hydroxyalkyl derivative is hydroxyethyl, hydroxypropyl or hydroxybutyl and the carboxyalkyl derivative is carboxymethyl.

60. A composition according to claim 56 or 57 wherein the amylose ester is a saturated fatty acid derivative.

61. A composition according to claim 60 wherein the fatty acid derivative is an acetyl or succinate derivative.

62. A composition according to claim 56 wherein the amylose alkyl succinate is starch octenyl succinate.

63. A composition according to any one of the claims 52 to 62 wherein the synthetic polymer is selected from the group consisting of polyethylene including low density polyethylene, linear low density polyethylene and high density polyethylene, ethylene vinyl acetate copolymers, ethylene acrylic acid copolymers, polyvinyl chlorides, polystyrenes, chlorinated polyethylenes, ethylene propylene copolymers, acrylic acid copolymers, polyvinyl acetals, polyamines, polyethylene terephthalates, phenolic resins and urethanes.

64. A composition according to any one of the claims 52 to 63 wherein the matrix is coated with the synthetic polymer.

65. A composition according to any one of the claims 52

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to 64 wherein the active agent is selected from the group consisting of acaricides, insecticides, nematocides, herbicides, fungicides, plant growth regulants, fertilizers, trace nutrients or a combination thereof.

66. A composition according to claim 65 wherein the active agent is chlorpyrifos, carbosulfan, carbofuran, phorate, diuron or cerechlor.

67. A composition according to any one of the claims 52 to 66 comprising a matrix including one or more fillers of a kind and in a concentration selected so as to control the rate of release of the active agent.

68. A composition according to any one of the claims 52 to 66 wherein the matrix further comprises a filler selected from the group consisting of metal salts, clays, carbonaceous material, dextroses, talcs, silicas and ammonium sulphate.

69. A composition according to claim 68 wherein the metal salt is calcium carbonate, calcium sulphate, sodium carbonate, sodium sulphate or barium sulphate.

70. A composition according to claim 68 wherein the clay is kaolin or bentonite.

71. A composition according to claim 68 wherein the carbonaceous material is wood flour.

72. A composition according to any one of the claims 68 to 71 wherein the filler is present in an amount of less than about 95% by weight of said matrix.



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73. A composition according to claim 72 wherein the matrix comprises filler in an amount of less than about 70% by weight.

74. A composition according to any one of the claims 52 to 73 wherein the matrix further comprises a plasticizer.

75. A composition according to any one of the claims 52 to 74 comprising water in an amount from about 1% to about 50% by weight.

76. A composition according to claim 75 comprising water in an amount of from about 2% to about 30% by weight.

77. A composition according to any one of the claims 51 to 76 having a dermal LD<sub>50</sub> as measured on rabbits which is less than the dermal LD<sub>50</sub> for the technical grade of said active agent as measured on rabbits.

78. A method for manufacture of a biodegradable matrix according to any one of the claims 1 to 50 further comprising the step of selecting the matrix composition and forming conditions so as to provide a predetermined rate of degradation and to include one or more fillers of a kind and concentration selected so as to vary the rate of release of the agent independently of said rate of degradation.

79. A method of agriculture which comprises applying to a crop growing area a biodegradable matrix shape according to claim 51 or a biodegradable composition according to any one of the claims 52 to 77.

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80. A method for manufacture of a biodegradable matrix shape substantially as herein described with reference to the examples and figures.

81. A biodegradable composition substantially as herein described with reference to the examples and figures.

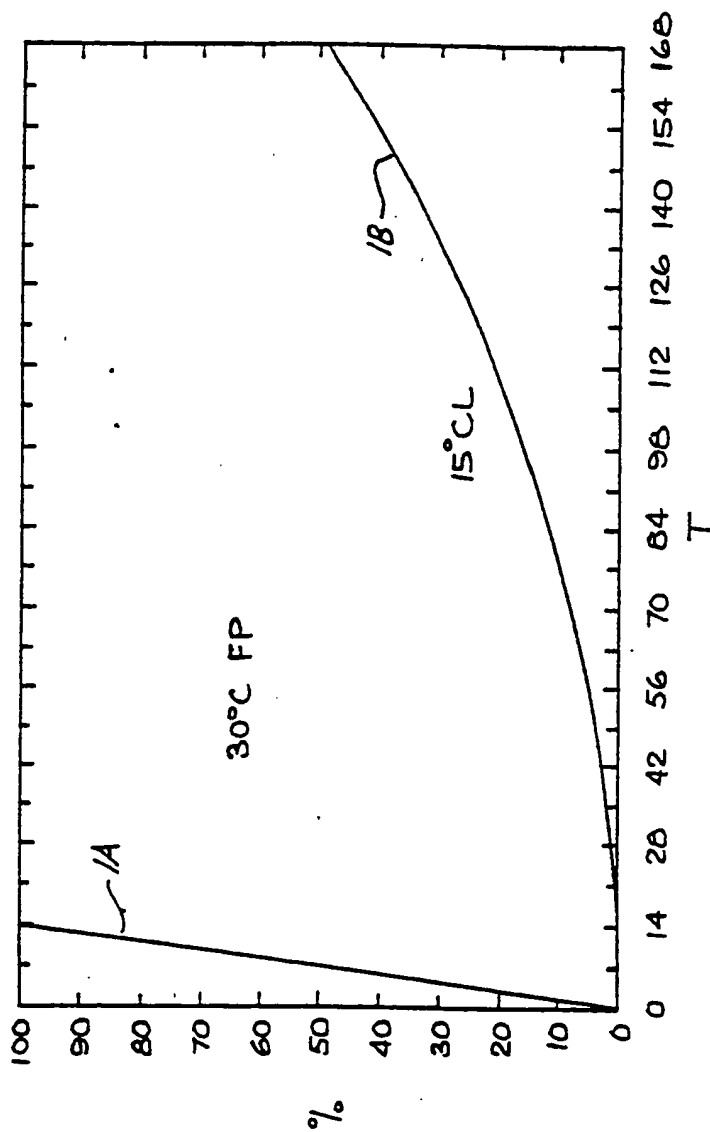


FIG. 1.

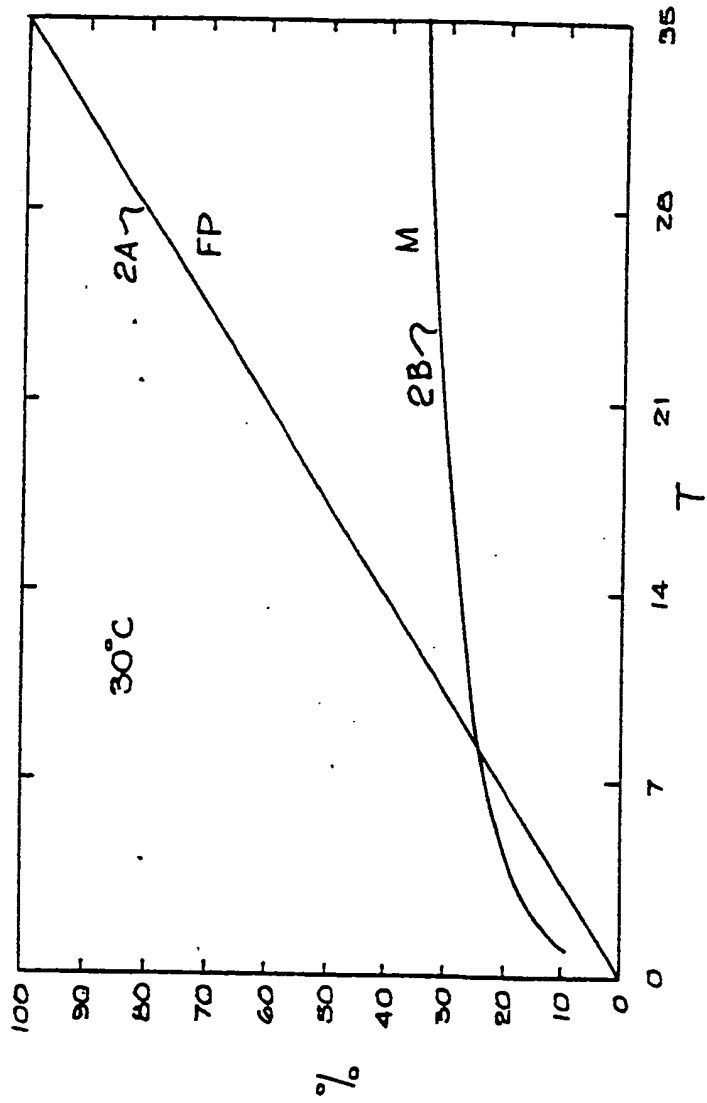
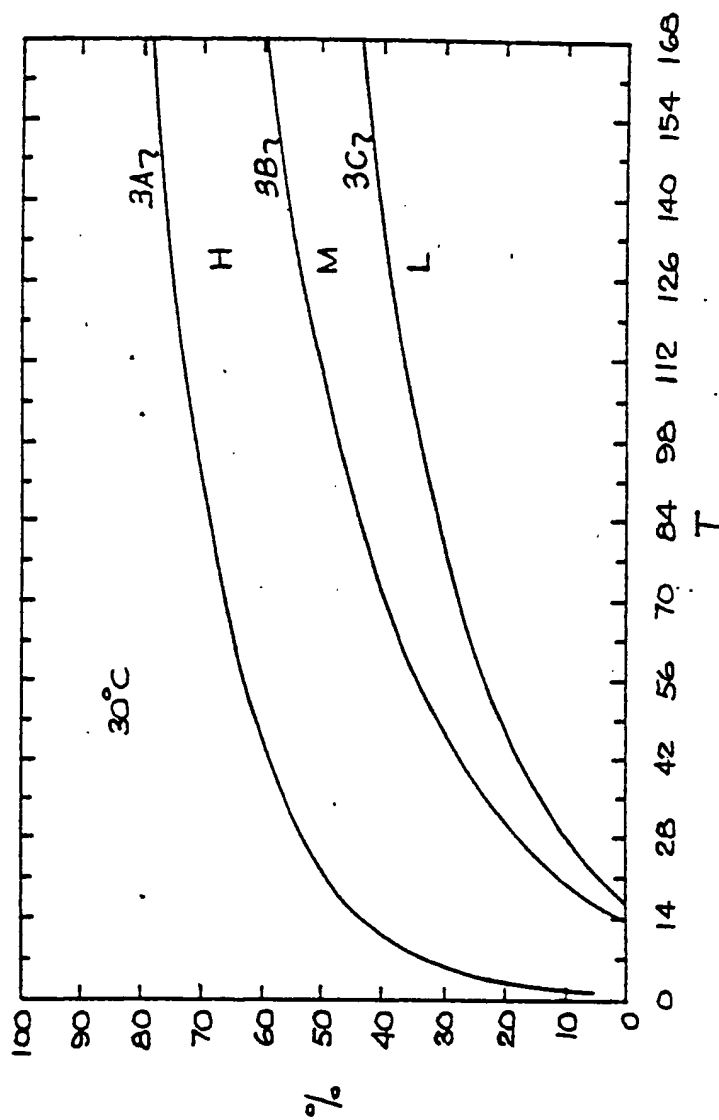
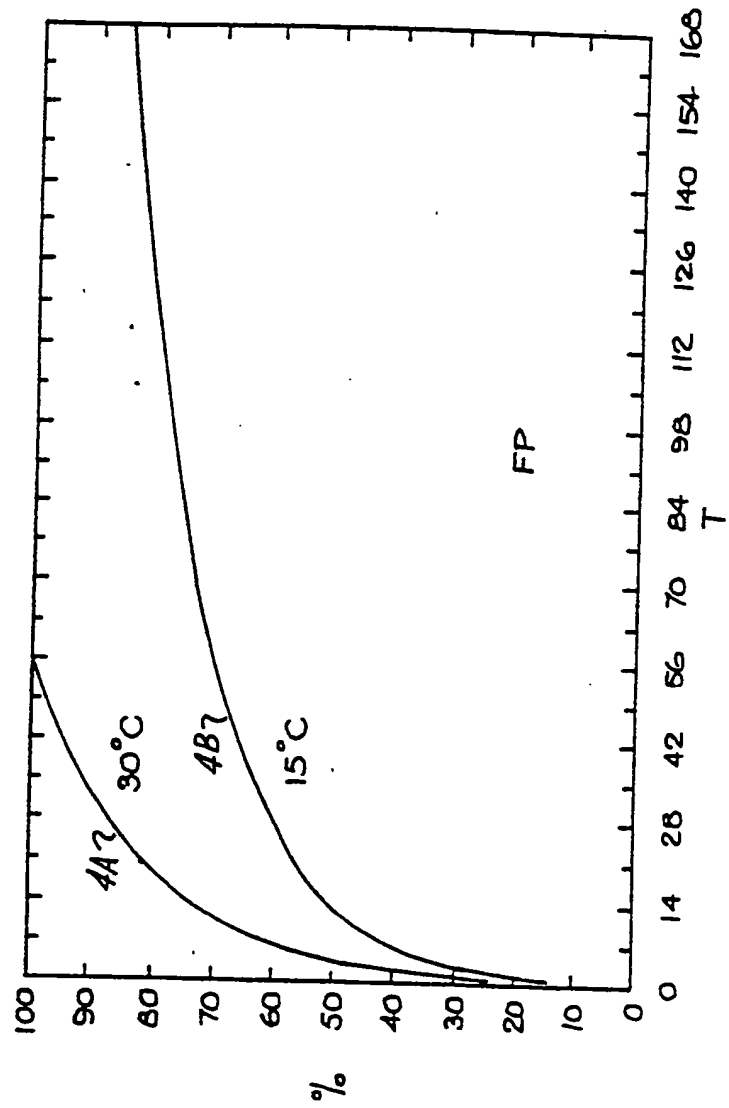


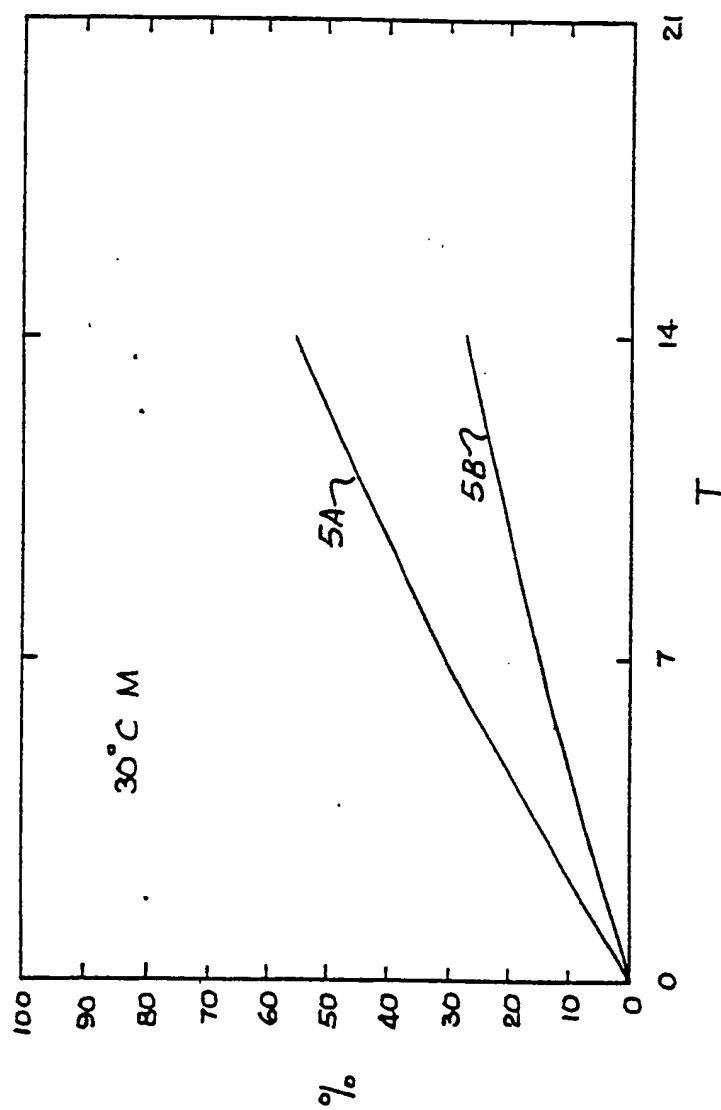
FIG. 2

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FIG. 3-

FIG. 4

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FIG. 5

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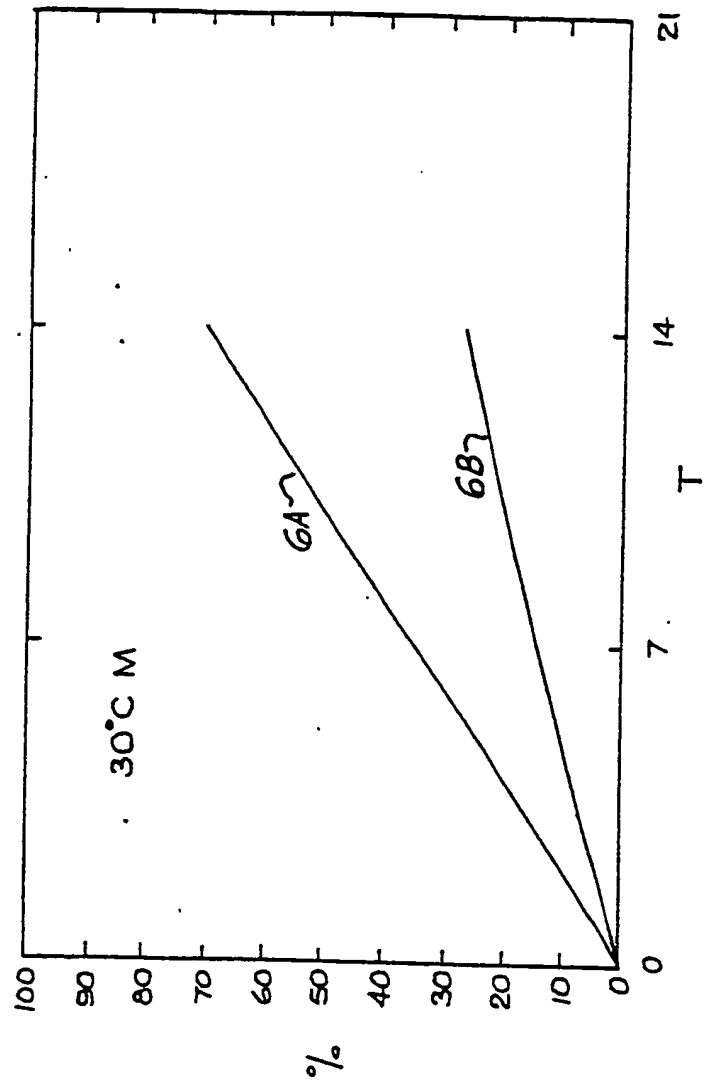
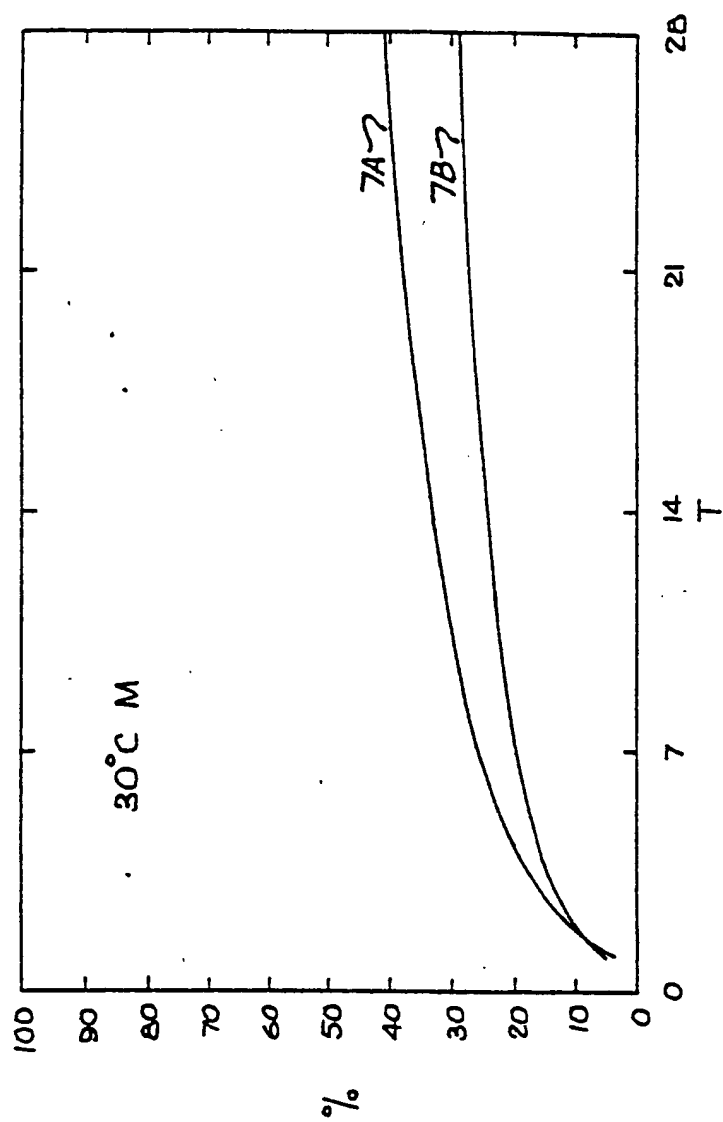


FIG. 6



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FIG. 7

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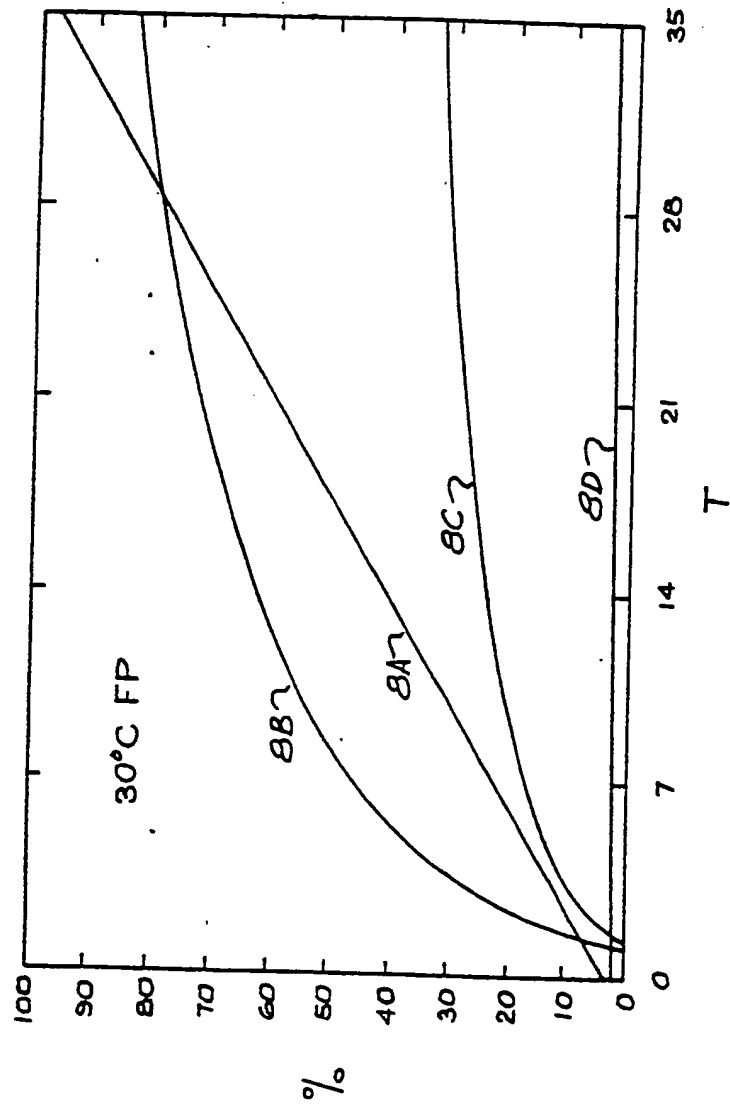


FIG. 8

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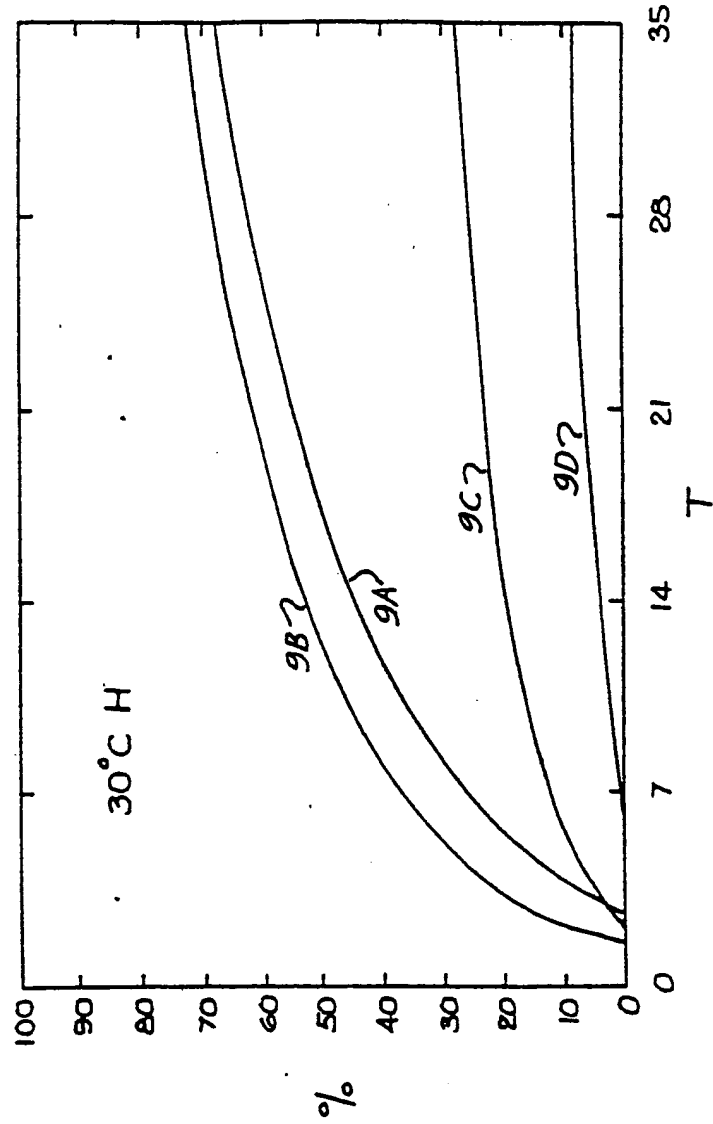


FIG. 9

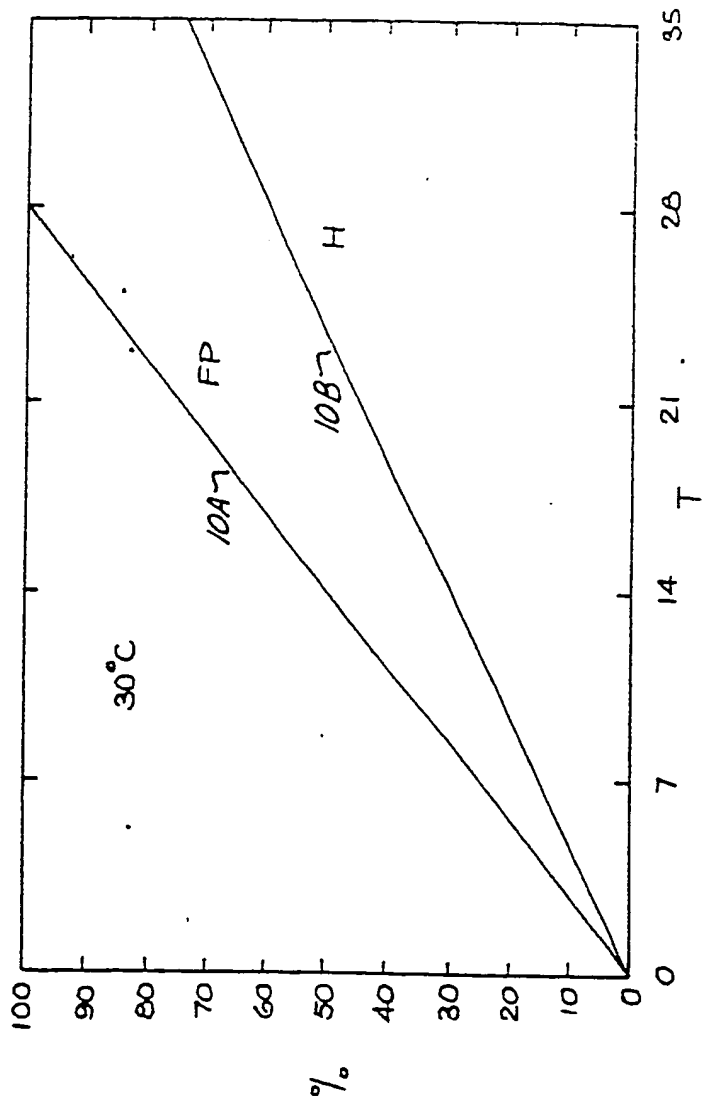


FIG. 10

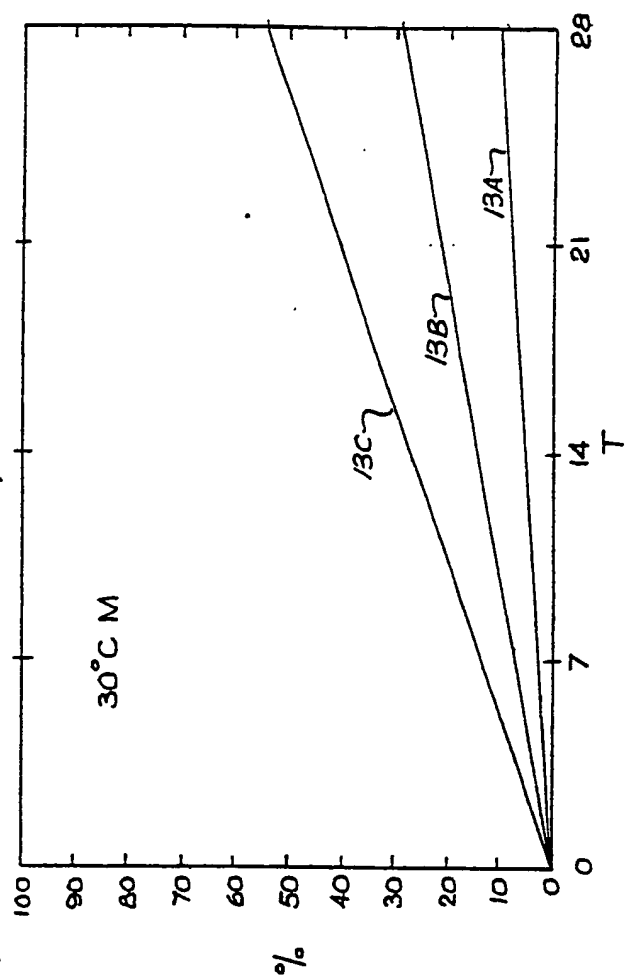


FIG. 13

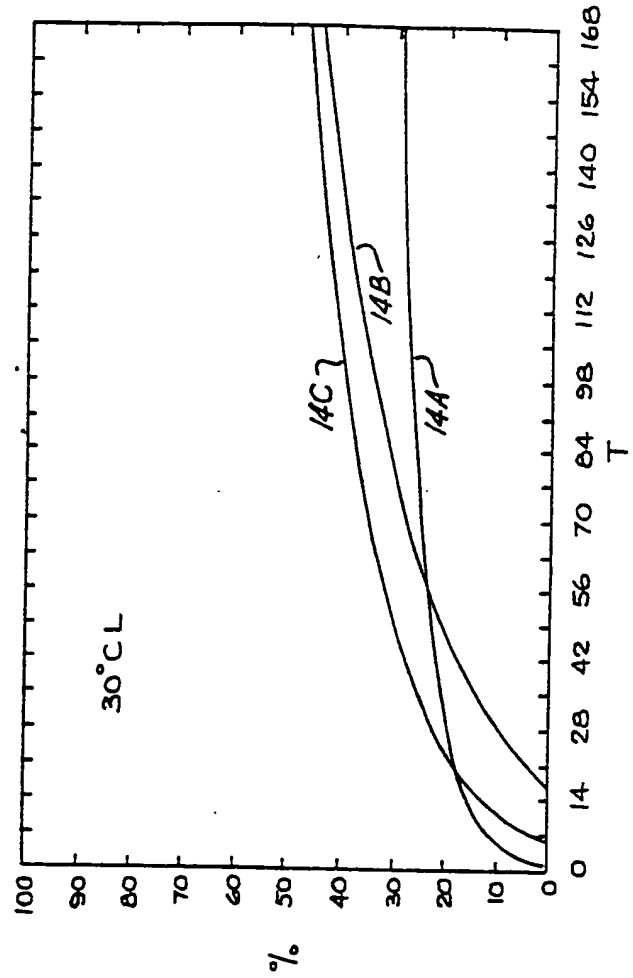


FIG. 14

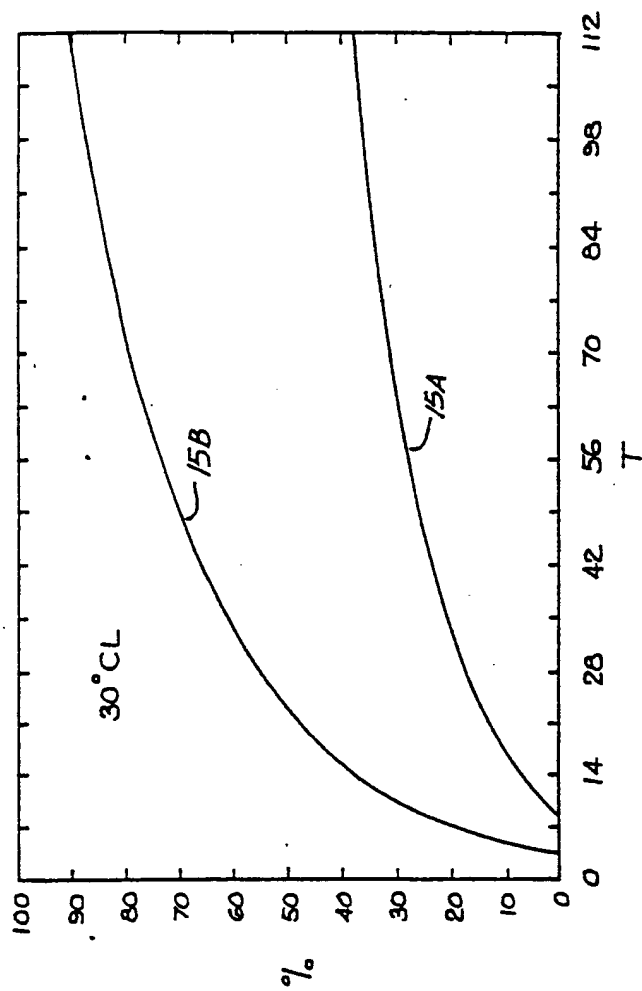
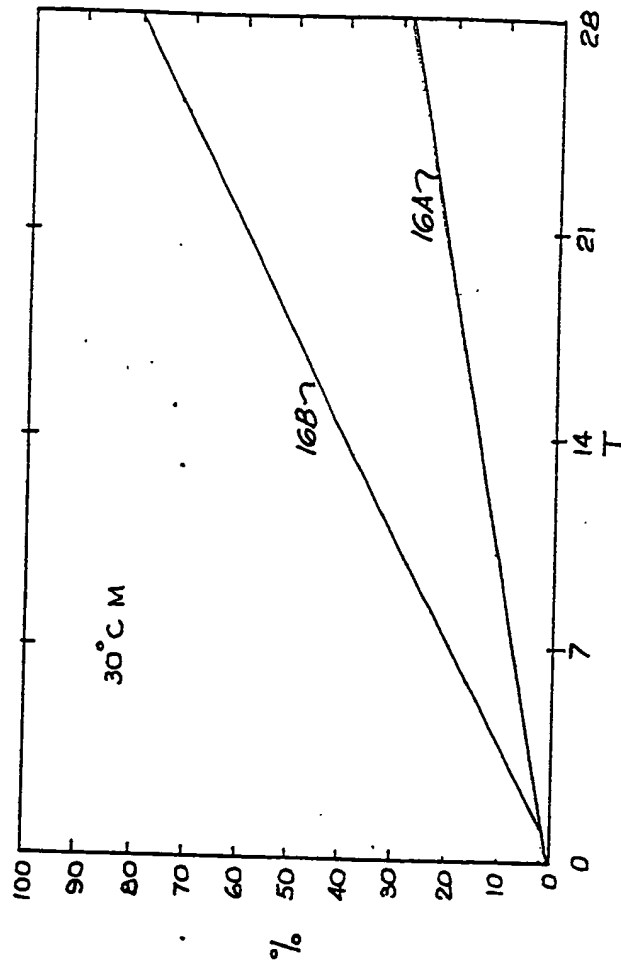
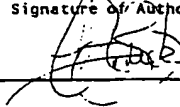


FIG. 15

FIG. 16



I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int. Cl. <sup>5</sup> A01N 025/10		
II. FIELDS SEARCHED		
Minimum Documentation Searched 7		
Classification System	Classification Symbols	
IPC	A01N 025/10	
Documentation Searched other than Minimum Documentation to the extent that such Documents are included in the fields Searched 8		
AU: IPC as above		
III. DOCUMENTS CONSIDERED TO BE RELEVANT 9		
Category*	Citation of Document, with indication, where appropriate, of the relevant passages 12	Relevant to Claim No 13
X	AU,A, 28876/89 (WARNER-LAMBERT) 3 August 1989 (03.08.89) See whole document, especially pages 3-5,8-12 and 19-24	(1-81)
Y	Patents Abstracts of Japan, C-167, page 130, JP,A, 58-39602 (NITTO DENKI KOGYO K.K.) 3 August 1983 (03.08.83)	(52-81)
P,X	DE,A, 3939721 (NIPPON GORSEI KAGAKU KOGYO K.K.) 7 June 1990 (07.06.90) See pages 1-9	(1-81)
X,Y	Industrial and Engineering Chemical Research, vol.26, No.8, 1987, pages 1659-1663; published by American Chemical Society (U.S.A.) F.H. Otey et al: "Starch-Based Blown Films. 2". See pages 1659 and 1661	(1-81)
(continued)		
* Special categories of cited documents: 10		
"A"	document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier document but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"O"	document referring to an oral disclosure, use, exhibition or other means	"G" document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed	
IV. CERTIFICATION		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
4 DEC 1990 (4.12.90)	17 December 1990	
International Searching Authority	Signature of Authorized Officer	
Australian Patent Office		C.A. BRICK

Y	U.S.A. 1987-01-01 - 1987-01-01 1987-01-01 - 1987-01-01	
X.Y	U.S.A. 85/00007- U.S.D. THOMPSON & SON, 14 March 1984 (1-1001864) See especially pages --6 and 11-12	(1-81)

V. [ ] OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [ ] Claim numbers .... because they relate to subject matter not required to be searched by this Authority, namely:
2. [ ] Claim numbers . because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. [ ] Claim numbers .... because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4 (a):

VI. [ ] OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING

This International Searching Authority found multiple inventions in this international application as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. [ ] As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

- [ ] The additional search fees were accompanied by applicant's protest.  
[ ] No protest accompanied the payment of additional search fees.

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